Arizona Department of Water Resources

WQARF Support Unit – Hydrology Division

Special Well Drilling Requirements
(For Wells Located Within Areas of Ground Water Contamination)

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ARIZONA
DEPARTMENT
OF WATER
RESOURCES

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Background

The intent of this document is to provide special guidance to drillers and well owners in constructing wells to protect ground water in areas of known or anticipated ground water contamination that are located in, or within close proximity to state Water Quality Assurance Revolving Fund (WQARF), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Department of Defense (DOD) sites. (View WQARF, CERCLA, DOD map). Additionally, these general guidelines should be followed in any area of known ground water contamination such as Resource Conservation and Recovery Act (RCRA) or Leaky Underground Storage Tank (LUST) sites. These requirements apply to contamination areas not covered by site-specific requirements (see below). A.R.S. § 45-605 (E) requires that ADWR develop a review process for all applications to drill, deepen, or modify a well located in an area of known or anticipated ground water contamination to insure that proposed wells are designed in a manner to prevent vertical-cross contamination.

Vertical cross-contamination is defined under A.R.S. §45-605(A) by reference to A.R.S. § 49-281[15], to mean "the vertical migration of released hazardous substances in ground water through a well from an aquifer or aquifer layer to another aquifer or aquifer layer".

Although a Notice of Intent (NOI) to drill will still be reviewed by ADWR prior to obtaining a drill card if your well location is within one (1) mile of a WQARF, CERCLA, or DOD site, this guidance is intended to provide general well drilling requirements within these areas of concern.

Please note that specific well drilling and well abandonment requirements cited in this document apply in addition to other ADWR statutes, rules, and substantive policy statements that regulate the drilling and abandonment of wells:

- Statutes and Rules Governing Minimum Well Construction Standards and the Licensing of Well Drillers (2001),

and

- Substantive Policy Statement Well Abandonment Handbook (September 20, 2001).

Well owners and drillers should use site-specific well construction and abandonment procedures developed for the following sites for which detailed guidance can be found:

Site-Specific Well Construction and Abandonment Procedures
Pinal Creek WQARF site
Yuma Marine Corps Air Station CERCLA site

For all other sites please follow the requirements outlined below:

Special Well Drilling Requirements

Sealing Requirements

- Wells penetrating multiple aquifers or aquifer layers must seal the annular space between the casing and borehole by placing a grout seal 25 feet above and 25 feet below aquifer contacts for a total of 50 feet of seal between the defined aquifers or aquifer layers. See Appendix A for applicable definitions. Depth to aquifer or aquifer layer contacts will vary with specific site locations. Reference data for aquifers or aquifer layers for most WQARF, CERCLA, and DOD sites can be found in an attached compiled list (Appendix B). This listing includes but should not be limited to ADWR ground water modeling reports, ADWR hydrologic map series, and U.S.G.S. water resources investigation reports. A driller should use their own knowledge of the aquifer system and review available data such as provided by ADEQ Project Managers for specific WQARF, CERCLA, and DOD site information.

Seal Material

- The seal material must be no more permeable than the formation being sealed. A target hydraulic conductivity of 10^{-7} cm/s may be used for sealant materials. The types of acceptable materials or mixtures are: cement grout (including neat cement grout and cement bentonite grout), high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips or high-solids bentonite pellets. See Table 1. for mixing ratios. A minimum of 15% solids bentonite will be acceptable in most cases. However, a higher minimum of bentonite solids, such as 25%, may be necessary in areas of high water quality contamination. Acid resistant cement (see definitions) should be used in certain areas where corrosive (low pH) ground water conditions are encountered.

- If there is no free-product contamination at the well site, the vadose zone portion of the well may be sealed with the same material that is used to seal the well below the water level. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications if used in the vadose zone. If free-product contamination issues exist, the vadose zone portion of the well must be sealed with neat cement grout.

Sealing Methods

Materials or mixtures must be emplaced under sufficient pressure to fill all voids, including all annular space(s), and displace water from the well. A tremie pipe must be used to emplace the grout from the bottom up. The end of the tremie pipe must remain in close proximity to the rising grout surface, as the grout is pumped into the well.

Well Screens

- Screening intervals or casing perforations shall not extend across defined aquifer boundaries. A good rule of thumb is to extend perforated intervals to only within 25 feet of a known aquifer boundary.

- Similarly, wells with multiple screened intervals may not be completed in more than one aquifer or aquifer layer. This is to prevent vertical cross-contamination from contaminants between overlying or underlying ground water zones.

- Wells that are in need of a greater yield than can be provided from screening within only one aquifer or aquifer layer should drill through the known vertical extent of contamination and complete an outer conductor casing to a minimum of 50 feet below the extent of contamination. Drilling and well completion can then continue after the grout material has set, completing the well through multiple aquifers as needed for production.

Other Well Construction Considerations

- Additionally, there should be at least 2 inches of annular space between the casing and the borehole to allow for sufficient emplacement of grout, bentonite, or filter pack materials (EPA, March 1991, p. 86).

- As stated within the *Statutes and Rules Governing Minimum Well Construction,* all joints shall be waterproof to prevent leakage of fluids. Threaded flush joints are preferred within areas of known ground water contamination (EPA, March 1991, p. 85). The casing material must be chemically inert with contaminants of concern within the ground water as recommended by EPA, March 1991, p.75.

- Three to five feet of fine silica sand (less than approximately 0.25-millimeter diameter) shall be placed over filter pack material when such material is used.

REFERENCES

Arizona Department of Water Resources, 2001. Statutes and Rules Governing Minimum Well Construction Standards and the Licensing of Well Drillers.

_____, September 20, 2001. Substantive Policy Statement - Well Abandonment Handbook .

ADWR WQARF Support Unit, 2002, Special well construction and abandonment procedures for Yuma Marine Corps Air Station CERCLA site June 2002. 12 p.

_____, 1998, Special well construction and abandonment procedures for Pinal Creek WQARF site . 11 p.

U.S.E.P.A., March 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development. EPAJ600/4-89/034, pp. 40-86.

Table 1.
Acceptable Seal Materials and Mixtures

Category	Specific Material	Mixing Ratio		Permeability (cm/sec)	Special Considerations
		Solids	Water		
Cement, Sand, Concrete & Bentonite Mixtures [1]	Neat Cement **or** Neat Cement Grout	One 94 pound sack of cement	Not more than six (6) gallons water	10^{-5} to 10^{-7}	Must be pumped with tremie pipe. Not for use in low pH environments.
	Cement-Bentonite Grout	One sack of cement (94 lb.) & 3-5 lbs. bentonite	Not more than six and one-half (6.5) gallons water	10^{-5} to 10^{-11}	Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist.
	Acid Resistant Cement (Pozzolanic Cement)	One sack of cement (94 lb.) and seventy-four (74) lbs. pozzolans (fly-ash, perlites, etc.) 2% to 6% of bentonite by weight is needed if perlites are used	Not more than ten (10) gallons of water per sack of cement	—	Typically used in areas where low pH groundwater is encountered. If perlites are used bentonite is needed to keep perlites from floating. Chemical admixtures and plastizers may be used to reduce viscosity.
Forms of Bentonite [1,2]	High-Solids Bentonite Grout (powder or granular mixture) with a minimum 15% solids by weight Minimum grout density = 9.2 lbs./gallon	*Fifty (50) lbs. dry bentonite powder (powder mixture)* or One hundred fifty (150) lbs. granular bentonite & 1 qt. Polymer (granular mixture)	Thirty–four (34) gallons (powder mixture) **or** One hundred (100) gallons (granular mixture)	10^{-7} to 10^{-8}	A minimum of 15% solids bentonite will be acceptable in most cases. However, a higher minimum of bentonite solids may be required in areas of high water quality contamination. Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist. Granular mixtures generally require the addition of polymers.
	High-Solids Bentonite Grout (powder or granular mixture) with a minimum 25% solids by weight Minimum grout density = 10.0 lbs./gallon	Fifty (50) lbs. dry bentonite powder (powder mixture) **or** One hundred fifty (150) lbs. granular bentonite & 1 qt. Polymer (granular mixture)	Eighteen (18) gallons (powder mixture) **or** Fifty-four (54) gallons (granular mixture)	10^{-8} to 10^{-9}	Cannot be used if free-product contamination issues exist. Granular mixtures generally require the addition of polymers.
	High-Solids Bentonite Chips and Pellets	NA	NA	—	Rate of pour should not exceed 50 lbs. / 5 minutes. Must be hydrated to manufacturer's specifications if used in vadose zone. Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist.

Notes: 1) Additives will be considered on a case by case basis (i.e., fly ash, CaCl, etc.).
2) Manufacturer's specifications should be followed to achieve a minimum 15% and 25% solids mixtures–mixing ratios listed in this table are approximate.

APPENDIX A

DEFINITIONS

For the purposes of this document, the following terms have the following meanings:

Acid Resistant Cement (also known as Pozzolanic cement) (generic mixture): means a cement mixture that has improved resistance to corrosive fluids. Acid resistant cement is developed by adding silicious materials, pozzolans, to Portland cement. Pozzolans from both natural materials of volcanic origin such as perlites (volcanic ashes), heat treated clays, shales, tuffs, opaline cherts and diatomaceous earth, and artificial materials consisting of by-products from glass factories, furnace slag, and fly ash may be used. A common mixing ratio is 74 pounds of pozzolans per 94 pound sack of cement and not more than ten (10) gallons of water per sack of cement. If perlites are used, 2 to 6 percent of bentonite by weight is needed to keep the perlite from floating. Acid resistant cement is typically recommended for well abandonment material in areas where low pH groundwater is encountered (such as near some mine sites).

Aggregate (generic mixture): means sand or gravel with particle size up to ¼ inch.

Annular Space: "means the space between the outer well casing and the borehole wall. An annular space also means the space between an inner well casing and an outer well casing." **A.A.C. R12-15-801(1)**

Aquifer: "means an underground formation capable of yielding or transmitting usable quantities of water." **A.A.C. R12-15-801(2)**

Aquifer Boundary: means a vertical change in aquifer properties indicated by a difference in hydraulic conductivity between aquifer layers that is at least greater than two orders of magnitude (100 times greater).

Bentonite "means a colloidal clay composed mainly of sodium montmorillonite, a hydrated aluminum silicate." **A.A.C. R12-15-801(5)**

Cement Grout or Grout: "means cement mixed with no more than 50 percent sand by volume, and containing no more than six gallons of water per 94 pound sack of cement." **A.A.C. R12-15-801(15)**

Cement grout is sometimes referred to as "sand-cement grout", when sand is in the mixture.

Grout is often used as a synonym for slurry which is a generic term that means a thin mixture of liquid, commonly water, and any of several finely divided substances such as cement or clay particles.

Cement-Bentonite Grout (generic mixture): means a mixture of cement, bentonite and water at a ratio of 6.5 gallons of water per each 94 pound sack of cement with not more than 3 to 5 pounds of bentonite per sack of cement.

Concrete or Concrete Grout (generic mixture): means a mixture of cement, sand, coarse aggregate and water, with not less than seven (7) 94 pound sacks of cement per cubic yard of mixture and not more than seven (7) gallons of water per sack of cement.

Free-Product Contamination: means any known hazardous substance that is essentially immiscible (non-soluble) in water. Some typical examples of free-product contamination are gasoline and carbon tetrachloride.

Hazardous Substance: has the same meaning prescribed by A.R.S. § 49-201.

High-Solids Bentonite Grout (granular or powder mixture) with a minimum of 15% solids by weight: means a mixture of granular bentonite or powder bentonite that yields a grout that has a minimum 15% bentonite solids by weight.

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High-solids bentonite grout with a minimum of 15% solids by weight can be prepared from a mixture of granular bentonite (nominal 8 to 20-mesh particle size), water and polymer at a ratio of one hundred-fifty (150) pounds of granular bentonite and one hundred (100) gallons of water premixed with one (1) quart of polymer.

High-solids bentonite grout with a minimum of 15% solids by weight can also be prepared from a mixture of bentonite powder (nominal 200-mesh particle size) and water at a ratio of fifty (50) pounds of dry bentonite powder and thirty-four (34) gallons of water.

High-Solids Bentonite Grout (granular or powder mixture) with a minimum of 25% solids by weight: means a mixture of granular bentonite or powder bentonite that yields a grout that has a minimum 25% bentonite solids by weight.

High-solids bentonite grout with a minimum of 25% solids by weight can be prepared from a mixture of granular bentonite (nominal 8 to 20-mesh particle size), water and polymer at a ratio of one hundred-fifty (150) pounds of granular bentonite and fifty-four (54) gallons of water premixed with one (1) quart of polymer.

High-solids bentonite grout with a minimum of 25% solids by weight can also be prepared from a mixture of bentonite powder (nominal 200-mesh particle size) and water at a ratio of fifty (50) pounds of dry bentonite powder and eighteen (18) gallons of water.

High-Solids Bentonite Chips: means chips of coarse bentonite ranging in size from 0.25 to 0.75 inch.

High-Solids Bentonite Pellets: means pellets of fine compressed bentonite (200-mesh) ranging in size from 0.25 to 0.50 inch.

Neat Cement or Neat Cement Grout (generic mixture): means a mixture of one (1) 94 pound sack of cement with not more than six (6) gallons of clean water.

Pressure Grouting "means a process by which a grout is confined within the borehole or casing of a well by the use of retaining plugs, packers, or a displacing fluid by which sufficient pressure is applied to drive the grout into and within the annular space or interval to be grouted." **A.A.C. R12-15-801(23)**

Sand-Bentonite Grout (generic mixture): means a mixture of equal parts sand and bentonite by volume with slightly more than one (1) gallon of water per pound of sand.

Sand-Cement Grout (generic mixture): means a mixture of one 94 pound sack of Portland cement, sand and water in the proportion of not more than one (1) part by volume of sand to one (1) part of cement with not more than six (6) gallons of water per 94 pound sack of cement.

Sealing: means the conscious effort to construct a positive permanent barrier within a well that restricts or prohibits the vertical movement of groundwater and/or any other fluids or materials.

Vadose Zone Contamination Issue: means any hazardous substance that is found in the vadose zone at or in the vicinity of the well at concentrations that exceed established state or federal standards.

Water Quality Contamination Issue: means any known hazardous substance that is found in groundwater at or in the vicinity of the well at concentrations that exceed established state or federal standards.

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Well: means any man-made opening in the earth through which water may be withdrawn or obtained from beneath the surface of the earth including: 1) all water wells, monitor wells and piezometer wells; 2) geothermal wells for which the rules of the Arizona Oil and Gas Commission do not require the reinjection of all water associated with the geothermal resource to the producing strata; and 3) all exploration wells and grounding or cathodic protection holes, except those that are less than 100 feet in depth and do not encounter groundwater.

Well Abandonment "means the modification of the structure of a well by filling or sealing the borehole so that water may not be withdrawn or obtained from the well." **A.A.C. R12-15-801(28)**

APPENDIX B

Selected References Containing Information on Aquifer Boundaries and Ground Water Flow Conditions in Arizona (Geographically Indexed)

Phoenix AMA

ADWR, 1990, Groundwater flow and contaminant transport modeling of North Indian Bend Wash Maricopa County, Arizona.

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Pool, D.R., Carruth, R.L., Meehan, W.D., 2001, Hydrogeology of Picacho Basin, South-Central Arizona. US Geological Survey Water-Resources Investigations Report 00-4277. 67 p.

Wickham, M.P., and Corkhill, E.F., 1989, Pinal AMA regional groundwater flow model - Phase One: Hydrologic framework, water budget and phase one recommendations. ADWR Modeling Report No.1. 63 p.

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Pinal Creek WQARF Site

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Prescott AMA

Corkhill E.F., and Mason, D.A., 1995, Hydrogeology and simulation of groundwater flow Prescott AMA – Yavapai County, Arizona. ADWR Modeling Report No. 9. 143 p.

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Remick, W.H., 1983, Maps showing groundwater conditions in the Prescott Active Management Area, Yavapai County, Arizona—1982. ADWR Hydrologic Map Series Report Number 9.

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Yuma Area

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Hill, B.M., 1993, ADWR in cooperation with Yuma County Flood Control District – Hydrogeology, numerical model and scenario simulations of the Yuma area groundwater flow model Arizona, California and Mexico. ADWR Modeling Report No. 7. 118 p.